STCE Newsletter

23 Jun 2025 - 29 Jun 2025

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The Solar-Terrestrial Centre of Excellence (STCE) is a collaborative network of the Belgian Institute for Space Aeronomy, the Royal Observatory of Belgium and the Royal Meteorological Institute of Belgium.

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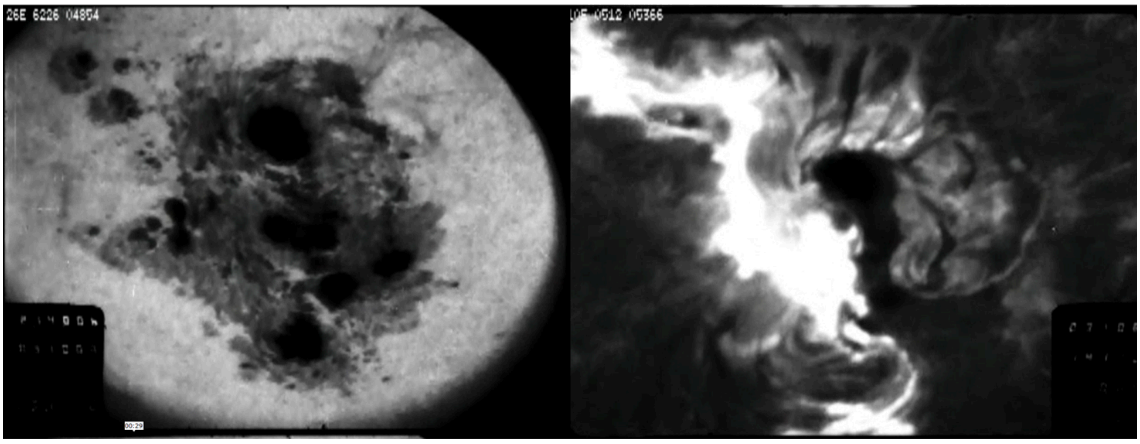
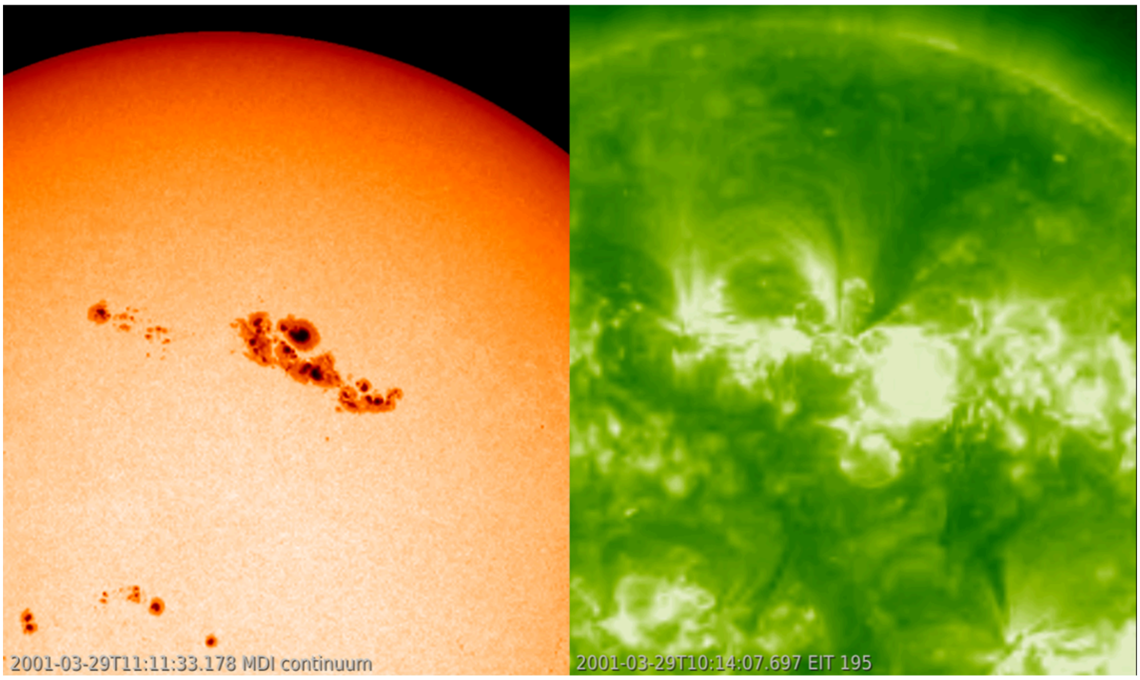
1. Superactive regions

Solar flares are violent eruptions on the Sun, often produced by complex, large sunspot groups. Intense solar flares may affect radio and satellite communcations, and radar operations. Applications based on GNSS (Global Navigation Satellite Systems, such as GPS and Galileo) may be impacted. Some of the flares may be accompanied by fast energetic particles ("proton events") or huge magnetic clouds filled with charged particles (coronal mass ejections or "CMEs"). When they arrive near the earth environment, they have their own specific impacts on very specific technologies. Many of these eruptions are produced by just a few very active sunspot groups, labeled superactive regions (SARs). Studying these SARs may reveal something about solar flare generation and about flares and spots on other stars.

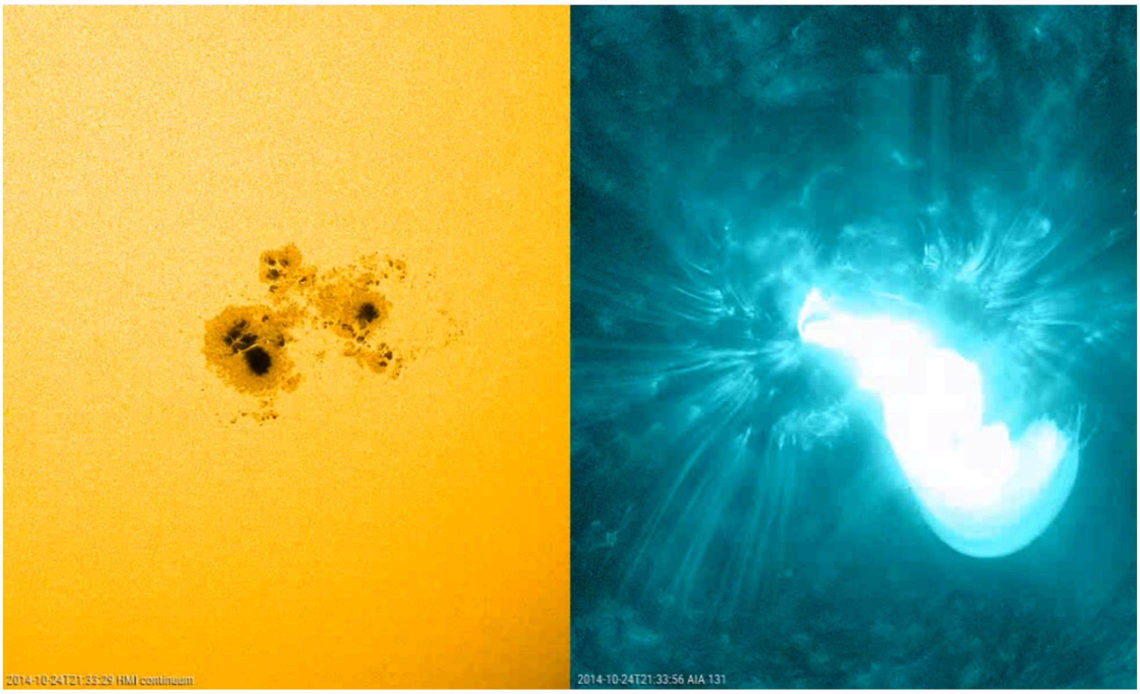
The images underneath show X-class events in SAR NOAA 5395 on 10 March 1989 (Credits Big Bear Solar Observatory / New Jersey Institute of Technology), NOAA 9393 on 29 March 2001 (SOHO MDI and EIT), NOAA 12192 on 24 October 2014 (SDO HMI and AIA), and NOAA 13664 on 11 May 2024 (SDO HMI and GOES SUVI). The white light image is on the left, the eruption is portrayed on the right in H-alpha or extreme ultraviolet.



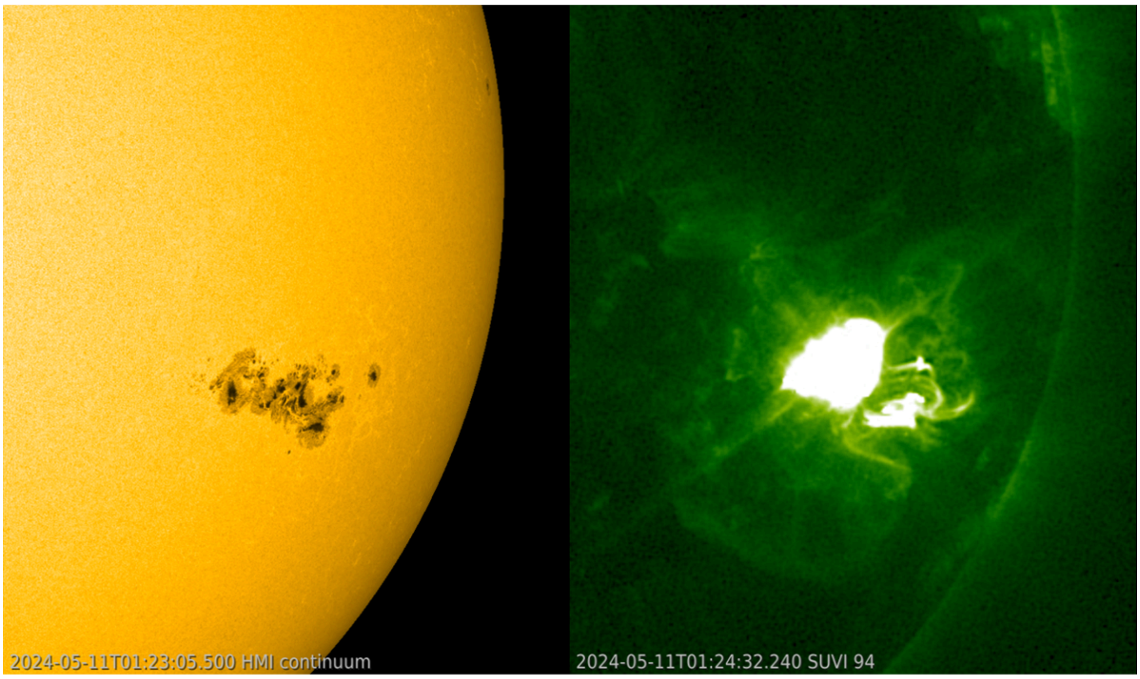
SARs have been studied since the late 1980s and have to satisfy some very specific criteria (Chen et al. 2011 - https://doi.org/10.1051/0004-6361/201116790). First, the parameters should be mostly independent, each providing a complementary insight into SAR physics. Secondly, these parameters should be easy to access, have a long time-interval coverage, and be contained in a database with standard calibrations. Thirdly, the number of parameters should be as small as possible to ensure that the selection of SARs is both simple and unique. Since the paper by Chen et al. 2011, the parameters and minimum thresholds that are usually employed to parameterize a SAR are (1) the maximum area of the sunspot groups must be at least 1000 MH, (2) the soft x-ray flare index should be at least 10, (3) there should be at least 1 associated radio burst at 10.7 cm with a peak flux of at least 1000 sfu, and (4) the shortterm total solar irradiance decrease (delta TSI) should be at least 0.1%. Note that the soft x-ray flare index is the sum of the numerical multipliers of M- and X-class flares of the active region, i.e. 0.1 for an M1 flare and 1.0 for an X1 flare. E.g. if an active region produces an X3.4 and an M7.0 flare during its transit, then the corresponding flare index is 4.1.



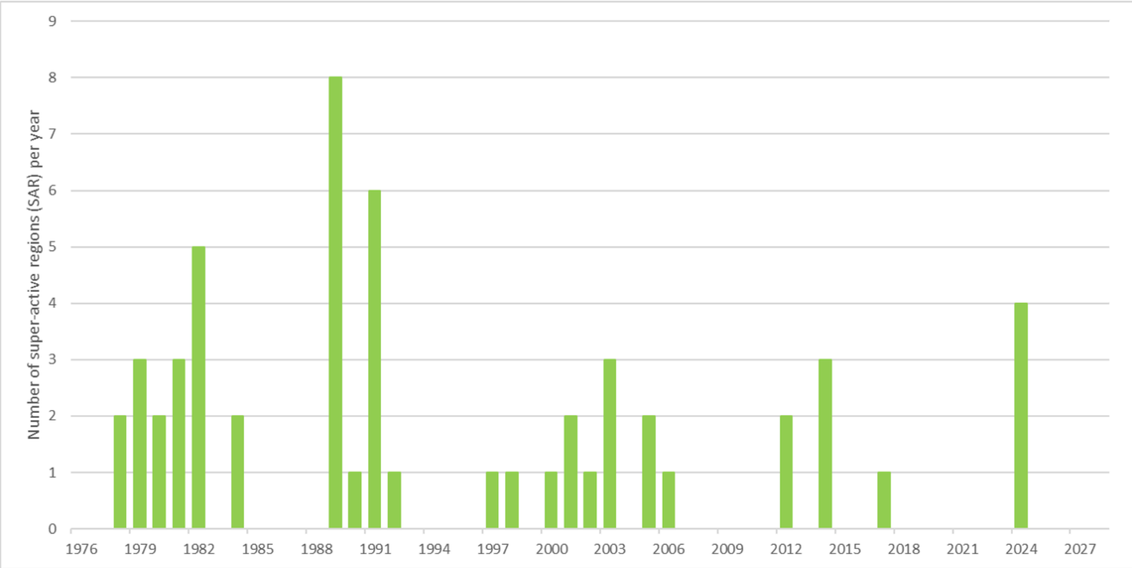
An active region is refered to as a SAR, if three of the four aforementioned conditions are fulfilled. An extreme flare-prolific active region may also be considered as a SAR if the soft X-ray flare index is larger than 15.0 and any one of the other criterion conditions is met. For the solar cycles SC21 to SC23, Chen et al. (2011) were able to identify 45 SARs that satisfied the set of conditions. The SARs in this 33-year period occupy only 0.44% of all the active regions in the three solar cycles, but produced an impressive 44% of all the X-class flares during the same time interval. The productivity was 4.13 X-class flares per SAR, which is two orders of magnitude larger than the productivity of an average active region. Also, based on SOHO coronagraphic observations starting from the mid 1990s, a very large majority of these SARs produced at least one CME with a velocity larger than 1500 km/s.



A few years ago, Chen and collaborators (Chen et al. 2022 - https://doi.org/10.1007/s11207-022-02076-4) then repeated the exercise for the weak solar cycle 24 (SC24). They were able to identify six SARs (0.31% of all the active regions in SC24) accounting for 30.6% of all the X-class flares in Solar Cycle 24. The SAR's productivity of X-class flares is about 100 times the average productivity of X-class flares for all active regions, which is consistent with the earlier findings for SC21-SC23. However, the productivity was only 2.5 X-class flares per SAR in SC24, much lower than the average of 4.13 X-class flares during the preceding three solar cycles. Four of the six SARs produced CMEs faster than 1500 km/s. All these results suggest that the activity level of SC24 was much weaker than that of the preceding solar cycles.



So, how is the ongoing SC25 doing? A quick survey of the available NOAA/SWPC data and the SIDC Total Solar Irradiance (TSI ; https://www.sidc.be/observations/space-based-timelines/tsi) composite (Dewitte et al. 2022 - https://doi.org/10.3390/rs14051072), taking into account the "upscaling" of the solar flares starting with GOES-16 (see https://www.stce.be/content/sc25-tracking#flares), reveals that there have been 4 SARs so far in SC25, all visible in 2024. There's no doubt about active regions NOAA 13664 and 13842, but NOAA 13663 and 13848 had to be deliberated for slightly too small sunspot area. These four groups represent 0.29% of all sunspot groups so far this solar cycle, producing 27.8% of all X-class flares. The productivity was 5.5 X-class flares per SAR, which is more than two orders of magnitude larger than the productivity of the other active regions. The graph underneath shows the number of SARs per year since the start of the GOES measurements in 1976. The 2024 value is of course preliminary.



2. Proba-3: top experts on coronagraphy meet

Meet the three instruments onboard Proba-3: ASPIICS, 3DEES and DARA

The 11th Science Working Team meeting of the ESA Proba-3 mission recently took place at Royal Observatory of Belgium (ROB). The world's top experts on coronagraphy, the technique to observe the solar corona by blocking the light of the solar disk, like during a total eclipse, met there for three days. Our colleague Andrei Zhukov, the principal investigator of the main instrument ASPIICS and his group, were the hosts. This meeting was much anticipated as it was the first after the ASPIICS images of an artificial total solar eclipse went public: ESA press release (https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Proba-3/Proba-3_s_first_artificial_solar_eclipse) and STCE press release (https://stce.be/content/proba-3-first-coronal-image).

Besides the solar eclipse maker ASPIICS that relies on the formation flying capabilities of the occulting and the coronagraph spacecraft, Proba-3 also carries the instruments 3DEES and DARA. 3DEES measures highly energetic particles present in two radiation belts around Earth. These typically fast moving particles impact satellites that fly through these zones. Our colleagues from the Royal Belgian Institute of Space Aeronomy (BIRA) have the lead in this instrument: energetic particles in the Earth environment is their expertise. The DARA instrument measures the energy of the solar light that arrives at Earth.

Numerous disciplines are needed to guarantee the success of the Proba-3 adventure

All the instrument teams were eager to present their first results. There was a lot to discuss on the details of the in-orbit operations of the two satellites. How Proba-3 cruises through space has an impact on the functioning of the instruments. Each orbit and each spacecraft manoeuvre gives better insight into what can happen and needs to be taken into account in the next observation campaigns. This is only part of the job. The main goal is gathering observations of the solar corona and measurements of the solar light and energetic particles. Each team has to prepare the data such that they go from raw measurements to something usable by researchers. The teams have to set up accessible databases where solar physicists and space weather researchers can easily find what they need. During this 3 days meeting, some preliminary research on Coronal Mass Ejections was already being presented. On top of all this, the gathering also set the path towards future collaborations with other space missions.

The 3 days were only the start of an exciting scientific space journey.

No time to waste, discussions run through the coffee breaks and lunches. It is key to understand the behaviour of the spacecrafts and the instruments, down to the level of the smallest screw, connection or pixel.

3. Nerdland science festival

Exactly one month ago, the STCE spread EUI sun shine at Nerdland.

Do you want to know what happened on the other side? https://stce.be/movies/Nerdland.mov

Nerdland: https://www.nerdlandfestival.be/nl/

4. ESWW2025 space weather training

You can apply for the space weather training in Kiruna, prior to the European Space Weather Week in Umea, Sweden.
Deadline is July 7.
Don't miss it: https://esww.eu/training/school-programme

5. Review of space weather

Solar Active Regions (ARs) and flares

Solar flaring activity was low, with only C-class flares. The largest flare was a C5.0 flare (SIDC Flare 4739) peaking at 12:23 UTC on June 23, which was produced by SIDC Sunspot Group 523 (NOAA Active Region 4114) which had a beta configuration of its photospheric magnetic field. There were 16 numbered active regions visible. The veta-gamma SIDC Sunspot Groups 527 and 530 (NOAA Active Regions 4118 and 4120) were the most complex regions.

Coronal mass ejections

Narrow coronal mass ejections (CME) were observed on NW limb in SOHO/LASCO-C2 on Jun 25 and Jun 27. They were associated with a partial filament eruptions on NW quadrant of the Sun. The erupted mass was part of an extended filament in the northern hemisphere. These CMEs did not arrive at Earth. A partial halo CME was observed in SOHO/LASCO-C2 images around 21:00 UTC on Jun 28 with a projected speed of about 500 km/s. It was associated with the C4.0 flare (SIDC Flare 4771, N06 W21, with peak at 19:54 UTC on June 28) from SIDC Sunspot Group 537 (NOAA Active Region 4126).

Coronal Holes

A recurrent negative polarity coronal hole (SIDC Coronal Hole 116) which spanned from 20 S to 30 N crossed the central meridian between Jun 21 and 25. A Co-rotating interaction region and followed by a high speed stream related to this coronal hole enhanced the solar wind parameters near Earth between Jun 25 and 29. Another recurrent negative polarity coronal hole (SIDC Coronal Hole 111) started to cross the central meridian on Jun 29.

Proton flux levels

The greater than 10 MeV GOES proton flux was at nominal levels throughout the entire week.

Electron fluxes at GEO

The greater than 2 MeV electron flux, as measured by GOES-19, briefly exceeded the 1000 pfu alert threshold level each day until Jun 25. The greater than 2 MeV electron flux, as measured by GOES-18 satellite, was above the threshold each day for a few hours until Jun 25. Both the electron fluxes were below the threshold level on Jun 26. From Jun 27, the greater than 2 MeV electron flux, as measured by GOES-19 and GOES-18 satellites, remained above the 1000 pfu threshold level most of the time. This was due to the high solar wind speed associated with the SIDC Coronal Hole 116 which crossed the central meridian between Jun 21 and 25.

Solar wind

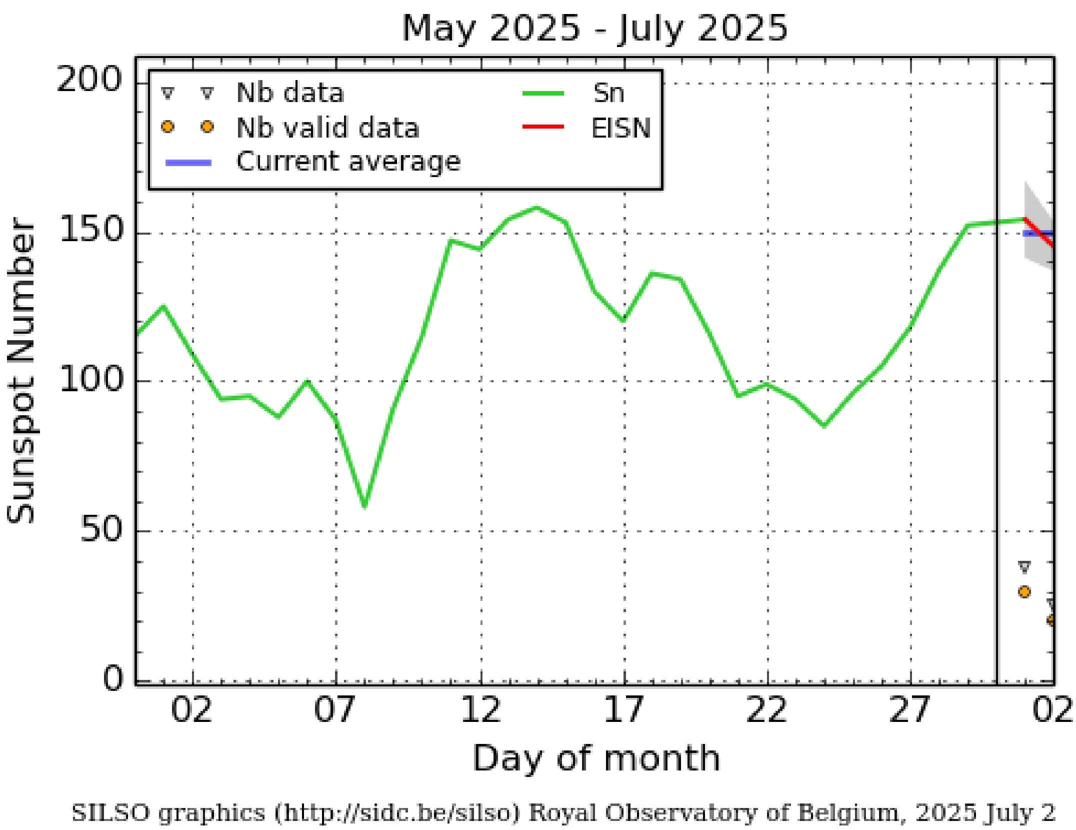
from the beginning of the week until Jun 24, the solar wind parameters were transitioning from fast to slow. A co-rotating interaction region, followed by a high speed stream (HSSs), related to the negative-polarity coronal hole (SIDC Coronal Hole 116) that crossed the central meridian between Jun 21 and

25, enhanced the solar wind parameters near Earth during Jun 25-29. During the entire week, the solar wind speed ranged from 355 km/s to 850 km/s. The North-South component (Bz) ranged between -12 nT and 14 nT. The interplanetary magnetic field ranged between 1 nT and 17 nT.

Geomagnetism

At the start of the week, geomagnetic conditions were at quiet to unsettled conditions (NOAA Kp and K_BEL 1 to 3) both globally and locally. With the arrival of the high speed stream associated to the negative-polarity coronal hole (SIDC Coronal Hole 116) that crossed the central meridian between Jun 21 and 25, geomagnetic conditions were globally at unsettled to minor storm conditions (NOAA Kp 3 to 5) between Jun 25 and 27, and locally it was at unsettled to active conditions (K_BEL 3 to 4). At the end of the week, the geomagnetic conditions were quiet to unsettled (NOAA Kp and K_BEL 1 to 3) both globally and locally.

6. International Sunspot Number by SILSO



The daily Estimated International Sunspot Number (EISN, red curve with shaded error) derived by a simplified method from real-time data from the worldwide SILSO network. It extends the official Sunspot Number from the full processing of the preceding month (green line), a few days more than one solar rotation. The horizontal blue line shows the current monthly average. The yellow dots give the number of stations that provided valid data. Valid data are used to calculate the EISN. The triangle gives the number of stations providing data. When a triangle and a yellow dot coincide, it means that all the data is used to calculate the EISN of that day.

7. PROBA2 Observations

Solar Activity

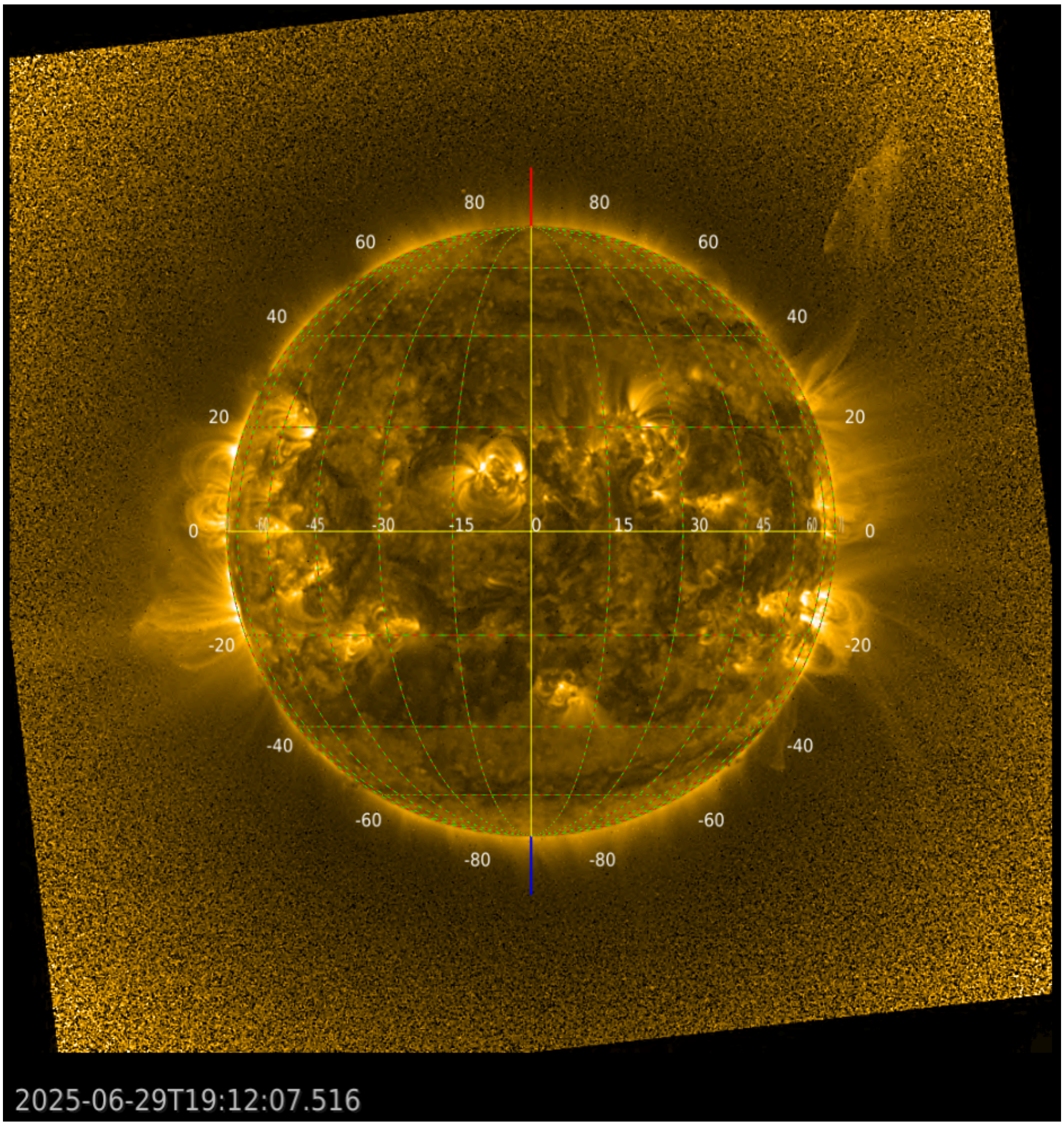
Solar flare activity was at a low level during the week, with no recorded M-class flares.
In order to view the activity of this week in more detail, we suggest to go to the following website from which all the daily (normal and difference) movies can be accessed: https://proba2.oma.be/ssa
This page also lists the recorded flaring events.

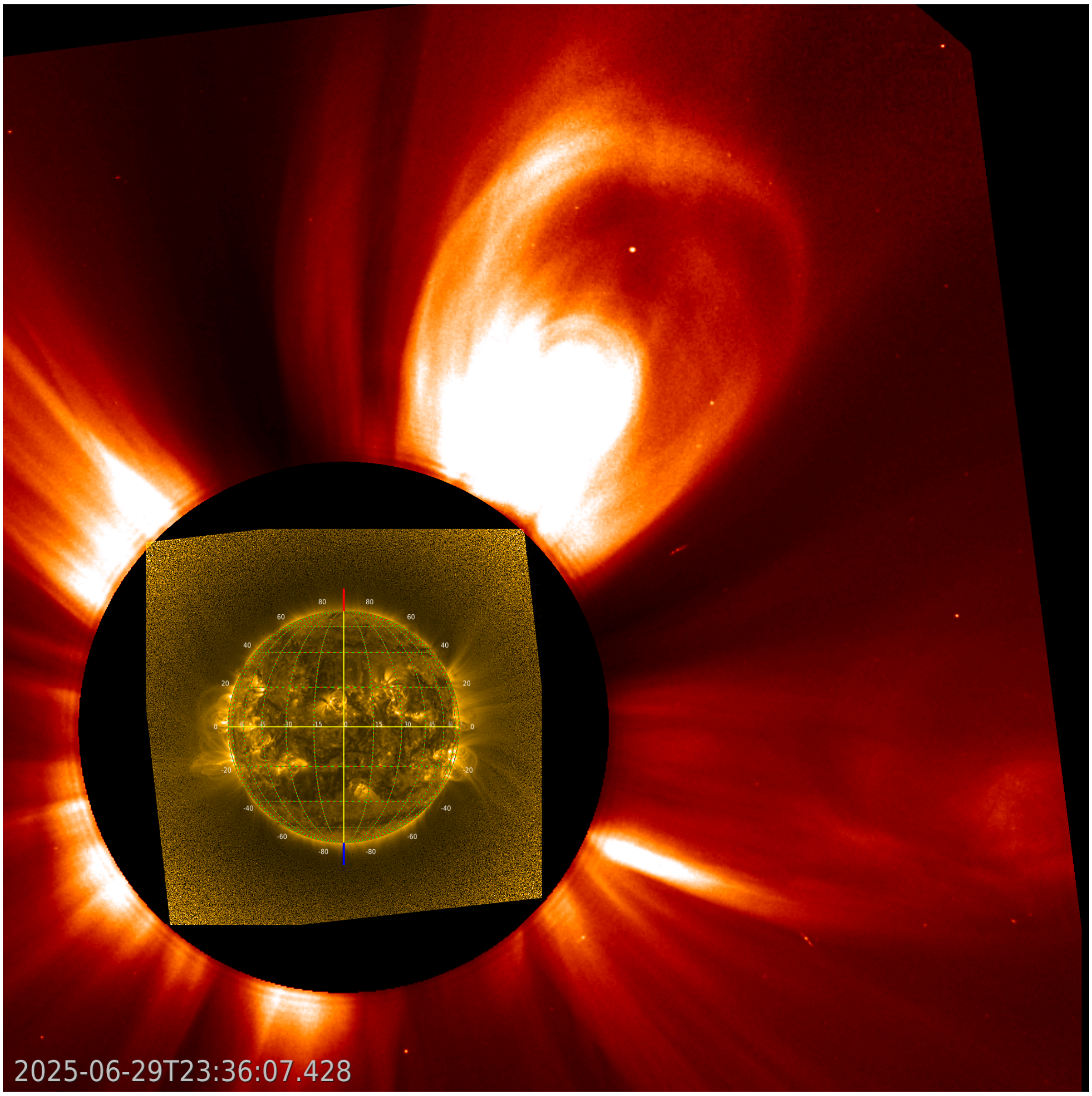
A weekly overview movie (SWAP week 796) can be found here: https://proba2.sidc.be/swap/data/mpg/movies/weekly_movies/weekly_movie_2025_06_23.mp4.

Details about some of this week's events can be found further below.

If any of the linked movies are unavailable they can be found in the P2SC movie repository here: https://proba2.oma.be/swap/data/mpg/movies/.

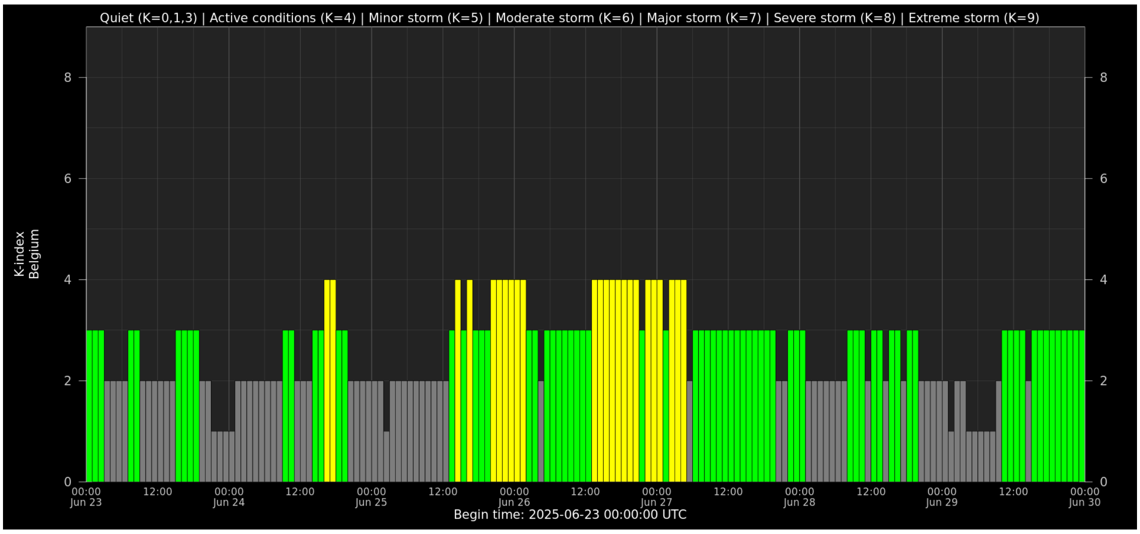
Sunday June 29





On Sunday, 2025-June-29 at ~18:00 UT there was a filament eruption which was observed by SWAP at the north-western limb of the Sun (top figure). The prominence slowly started lifting at the beginning of the day and was later on associated with a coronal mass ejection captured by LASCO-C2 coronagraph onboard SOHO spacecraft (bottom figure).
Find a SWAP movie of the event here: https://proba2.sidc.be/swap/movies/20250629_swap_movie.mp4.

8. Geomagnetic Observations in Belgium



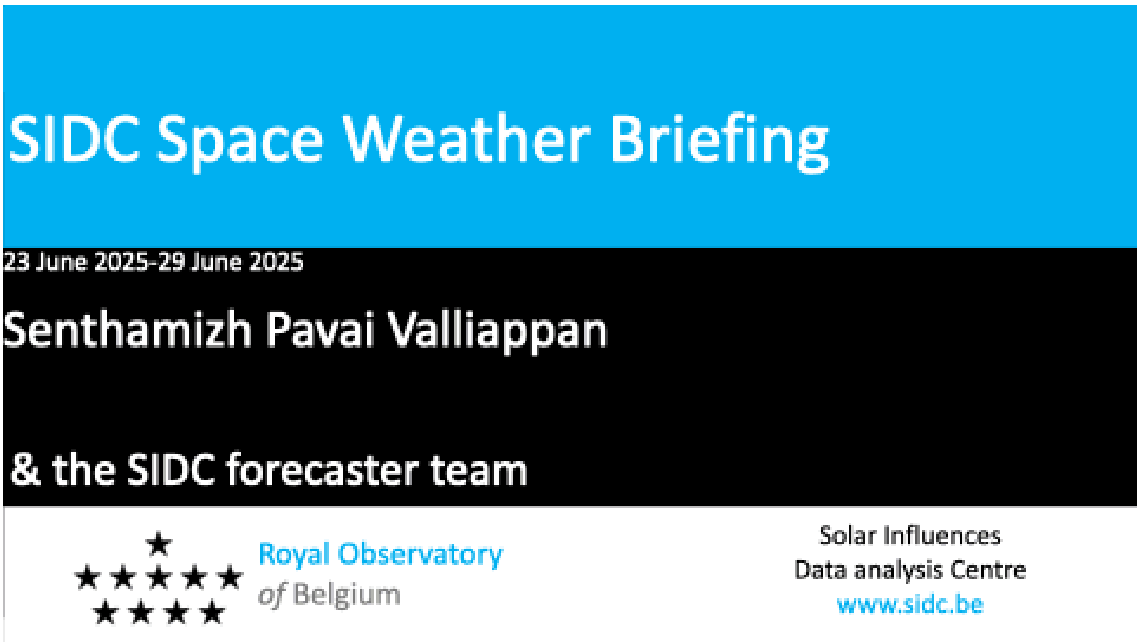
Local K-type magnetic activity index for Belgium based on data from Dourbes (DOU) and Manhay (MAB). Comparing the data from both measurement stations allows to reliably remove outliers from the magnetic data. At the same time the operational service availability is improved: whenever data from one observatory is not available, the single-station index obtained from the other can be used as a fallback system.

Both the two-station index and the single station indices are available here: http://ionosphere.meteo.be/geomagnetism/K_BEL/

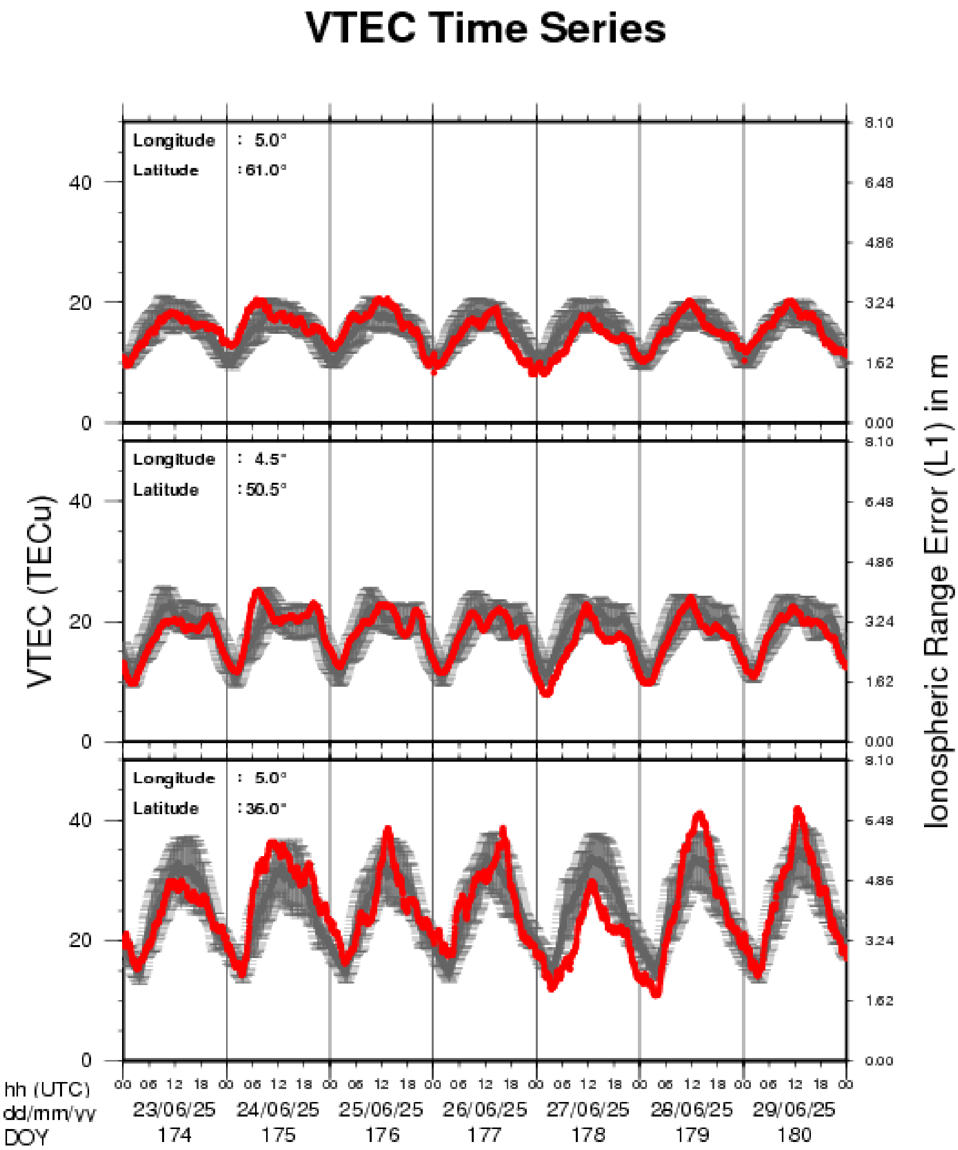
9. The SIDC Space Weather Briefing

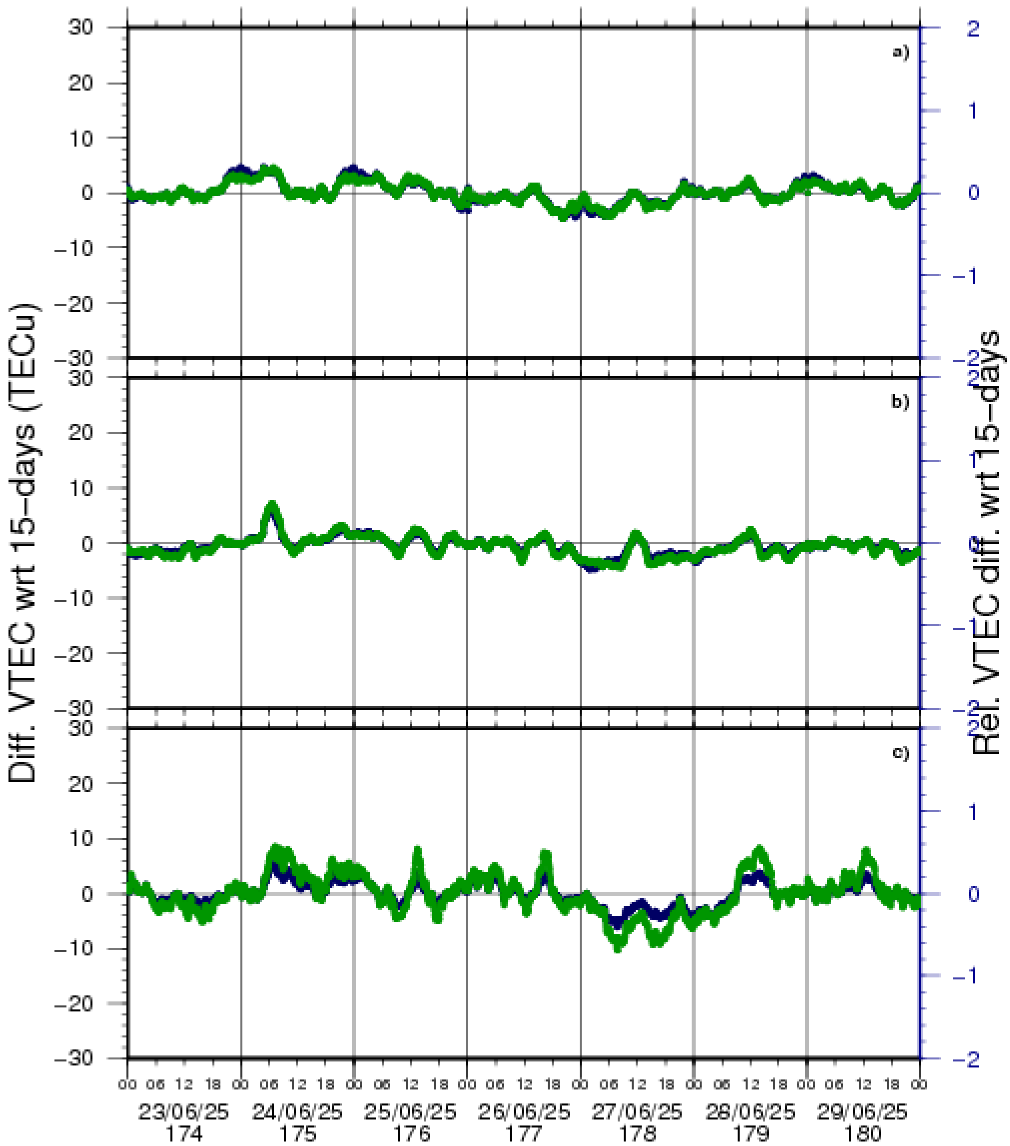
The forecaster on duty presented the SIDC briefing that gives an overview of space weather from to June 23 to June 29 .

The pdf of the presentation can be found here: https://www.stce.be/briefings/20250630_SWbriefing.pdf


SIDC Space Weather Briefing
23 June 2025-29 June 2025
Senthamizh Pavai Valliappan
& the SIDC forecaster team
Royal Observatory
of Belgium
Solar Influences
Data analysis Centre
www.sidc.be

10. Review of Ionospheric Activity





VTEC time series at 3 locations in Europe from 23 Jun 2025 till 29 Jun 2025

The top figure shows the time evolution of the Vertical Total Electron Content (VTEC) (in red) during the last week at three locations:
a) in the northern part of Europe(N 61deg E 5deg)
b) above Brussels(N 50.5deg, E 4.5 deg)
c) in the southern part of Europe(N 36 deg, E 5deg)
This top figure also shows (in grey) the normal ionospheric behaviour expected based on the median VTEC from the 15 previous days.

The time series below shows the VTEC difference (in green) and relative difference (in blue) with respect to the median of the last 15 days in the North, Mid (above Brussels) and South of Europe. It thus illustrates the VTEC deviation from normal quiet behaviour.

The VTEC is expressed in TECu (with TECu=10^16 electrons per square meter) and is directly related to the signal propagation delay due to the ionosphere (in figure: delay on GPS L1 frequency).

The Sun's radiation ionizes the Earth's upper atmosphere, the ionosphere, located from about 60km to 1000km above the Earth's surface.The ionization process in the ionosphere produces ions and free electrons. These electrons perturb the propagation of the GNSS (Global Navigation Satellite System) signals by inducing a so-called ionospheric delay.

See http://stce.be/newsletter/GNSS_final.pdf for some more explanations; for more information, see https://gnss.be/SpaceWeather

11. Courses and lectures

Courses, seminars, presentations and events with the Sun-Space-Earth system and Space Weather as the main theme. We provide occasions to get submerged in our world through educational, informative and instructive activities.

* Aug 25, Guest lecture: De Zon, Zomerschool Sterrenkunde, Vereniging voor Sterrenkunde, Leuven, Belgium
* Sep 1, STCE seminar: Ground-Based Windows to the Sun: Solar Observations with the Dutch Open Telescope
* Sep 8-10, STCE course: Role of the ionosphere and space weather in military communications, Brussels, Belgium - register: https://events.spacepole.be/event/226/
* Oct 23-25, ESWW Space Weather Training by Umea University and STCE, Kiruna, Sweden, https://esww.eu/training/application , deadline July 7
* Oct 27-31, European Space Weather Week, Umea, Sweden - https://esww.eu/
* Nov 17-19, STCE Space Weather Introductory Course, Brussels, Belgium - register: https://events.spacepole.be/event/217/

To register for a course and check the seminar details, navigate to the STCE Space Weather Education Center: https://www.stce.be/SWEC
If you want your event in the STCE newsletter, contact us: stce_coordination at stce.be

Website: https://www.stce.be/SWEC